AD-A077 496 DEFENSE ATOMIC SUPPORT AGENCY WASHINGTON DC F/G 6/18
OPERATION BUSTER PROJECT 6.1B EVALUATION OF DOSIMETRIC MATERIAL--ETC(U)
MAR 52 J CRYDEN, F P GIBSON

UNCLASSIFIED AEC-WT-317 NL

1 OF 1
ADA
077496

END
DATE
FILMED
12-79
DDC

PHOTOGRAPH THIS SHEET

ADA077496

DTIC ACCESSION NUMBER

II

LEVEL

INVENTORY

AEC

WT-317

DOCUMENT IDENTIFICATION

DISTRIBUTION STATEMENT A

Approved for public release;
Distribution Unlimited

DISTRIBUTION STATEMENT

ACCESSION FOR		
NTIS GRA&I		☒
DTIC TAB		☐
UNANNOUNCED		☐
JUSTIFICATION Per ltr. on file		
BY		
DISTRIBUTION /		
AVAILABILITY CODES		
DIST	AVAIL AND/OR SPECIAL	
A		

DISTRIBUTION STAMP

DDC

RECEIVED

DEC 3 1979

D

DATE ACCESSIONED

79 11 21 ~~024~~ 124

DATE RECEIVED IN DTIC

PHOTOGRAPH THIS SHEET AND RETURN TO DTIC-DDA-2

DTIC FORM OCT 79 70A

DOCUMENT PROCESSING SHEET

[redacted]

#217 Key list

ONA

DOE

DPOF

BUSTER

NEVADA PROVING GROUNDS
OCTOBER-NOVEMBER 1951

Project 6.1b

EVALUATION OF DOSIMETRIC MATERIALS

[redacted]

ARMED FORCES SPECIAL WEAPONS PROJECT
WASHINGTON, D.C.

[redacted]

CONFIDENTIAL

[redacted]

UNCLASSIFIED

[redacted]

This document contains information affecting the national defense of the United States within the meaning of the Espionage Laws, Title 18 U. S. C. Sections 793 and 794. The transmission or the revelation of its contents in any manner to an unauthorized person is prohibited by law.

CONFIDENTIAL

FORMERLY RESTRICTED DATA
HANDLE AS RESTRICTED DATA IN
FOREIGN DISSEMINATION
SECTION 144b, ATOMIC ENERGY ACT 1954

[redacted]

UNCLASSIFIED

UNCLASSIFIED

[redacted]

This document consists of 39 plus 4 pages (counting preliminary pages)

No. 199 of 345 copies, Series A

OPERATION BUSTER

PROJECT 6.1b

EVALUATION OF DOSIMETRIC MATERIALS

By

Mr. Joseph Cryden
1st Lt. Faison P. Gibson

21 March 1952

SIGNAL CORPS ENGINEERING LABORATORIES
AND
U. S. NAVY BUREAU OF SHIPS

[redacted]

[redacted]
ATOMIC ENERGY ACT

UNCLASSIFIED

UNCLASSIFIED

[redacted]

CONTENTS

[redacted]

UNCLASSIFIED

[redacted] ATOMIC ENERGY ACT [redacted]

TABLES

ILLUSTRATIONS

UNCLASSIFIED

[redacted]

ABSTRACT

Development models of several types of military personnel dosimeters were tested to determine their accuracy under exposure to the prompt radiation of an air burst. Included in the test were both self-indicating and non-self-indicating dosimeters, with various sensitivities encompassing the low range, high range, and casualty range of dosage. Dosimeters were arranged in arrays on aluminum plates, which were then covered by aluminum hemispheres. Film badges set inside National Bureau of Standards film holders designed to compensate for energy variations were used as controls. These shelters were then placed at varying distances from the bomb blast. Conclusions are reached and recommendations made with respect to the adequacy of the equipment for military applications.

[redacted]

UNCLASSIFIED

[redacted]
ATOMIC ENERGY ACT [redacted]

CHAPTER 1

INTRODUCTION

1.1 OBJECTIVE

The objective of this test was to evaluate certain types of military personnel dosimeters in the light of performance data obtained through exposure to the high dose rates and characteristic energy spectrum of the prompt radiation. Essentially, evaluation of performance of the dosimeters was to include consideration of the following factors:

1. Accuracy of dose indication (compared to a standard)

2. Consistency of dose indication (among units of same kind)

Evaluation of other characteristics such as ruggedness and ease of operation is more of a laboratory problem and was not an objective of this operation. Obvious deficiencies of such a nature of course would have been reported; however, none were noted.

1.2 HISTORICAL AND THEORETICAL

1.2.1 Navy

The Bureau of Ships has sponsored several approaches to the development of dosimeters suitable for the various military requirements. The program was directed toward meeting military characteristics specified by the Chief of Naval Operations. Equipments were desired to cover the low ranges, 200 mr, high ranges 200 r and the casualty range 600 r. To meet an immediate need for low range dosimeters procurements were initiated for quartz fiber dosimeters that would meet Navy specifications. Commercially available equipments were modified for this purpose. At present the IM-9 and IM-50 series dosimeters, designed to meet military specifications, are in production. In order to satisfy charging requirements for these equipments, procurement of an electrostatic charger that would meet military requirements was initiated. After considerable developmental work a satisfactory charger was designed and is now in production.

[redacted]

A broad program of research and development was initiated to determine the most suitable techniques for producing dosimeters that would meet all military requirements and which could be produced at low cost by mass production techniques. Investigations were concerned with the response of a wide variety of liquids and solids to ionizing radiations. Included in the studies were the tenebrescence of sensitized crystals, photoconductivity in irradiated alkali halides, and the piezoelectric effect. Emphasis was placed on the high dosage ranges because of the urgent need for equipment of this type.

Work at the Naval Research Laboratory, The Naval Medical Research Institute and at the Naval Radiological Defense Laboratory, as well as at commercial activities resulted in the development of a high range non-self-indicating dosimeter and a self-indicating casualty dosimeter. The high range non-self-indicating dosimeter originated at the Naval Research Laboratory. The sensitive element is a silver-activated phosphate glass. Following gamma ray exposure this fluoresces orange under near ultra-violet light. The casualty type uses a crystal sensitized by techniques studied first for this application at the Naval Research Institute in that it uses comparison scales to permit reading of the exposed crystal by color matching. The comparison scales are of blue dyed plastic, corresponding to doses of 50, 100, 200 and 400 roentgens. The glass type was developed to provide a more accurate measure of dosage. It provides for a continuous measure of dosage over the ranges 0-200 and 0-600 roentgens. With a suitable reader the range is greater. The minimum detectable dose is 10 roentgens.

In the crystal dosimeter, ionizing radiations produce the reaction: $H^- \rightarrow H^0 +$ electron (i. e., electrons are freed from negative hydrogen ions leaving neutral hydrogen atoms). The hydrogen diffuses away from the lattice site it occupied before the irradiation. The free electron is then trapped at the lattice site vacated by the hydrogen, forming an imperfection known as an "F" center. Since the "F" center absorbes light in the visible spectral range, the crystal becomes colored. Although in general pure alkali halide crystals normally have a small proportion of vacant negative-ion sites which can trap electrons released by ionizing radiations, the number of these vacancies in pure crystals is too small to give the sensitivity required for practical detection of gamma-rays below the lethal dose range. The incorporation of hydride ion as an impurity provides a means of creating vacancies in much larger concentration by the action of the ionizing radiation itself. Absorption of light by an "F" center results in ejection of the electron from the center, allowing recombination with the hydrogen to re-form hydride ion. Prolonged exposure to intense visible light thus bleaches the blue color in the KBr-KH crystal and returns it essentially to its original state.

The glass dosimeter operates on the principle of "radiophotoluminescence," which may be defined as the creation of new stable luminescent centers in a solid by the action of high-energy radiations. In the silver-activated glass the photochemical reaction caused by gamma-rays may be symbolized: $Ag^{+} + \text{electron} \rightarrow Ag^{o}$ (i.e., electrons freed by radiation unite with positive silver ions forming neutral silver atoms. The neutral silver atoms are new species not present in the original glass, in which the silver is combined entirely in the ionic form. Ionic silver (AG) does not absorb near-ultraviolet light, and hence the unexposed glass does not luminesce under such illumination. The neutral silver centers (Ag^{o}), on the other hand, absorb near ultraviolet light, which excites them to emit an orange luminescence. The intensity of this luminescence, measured in a simple fluorophotometer or "reader", is determined by the number of Ag^{o} atoms formed in the glass by gamma-radiation, and hence can be used as a measure of the dosage received by the glass.

1.2.2 Army

Under the impetus given by the Armed Forces Special Weapons Project, personnel and facilities were set up in the Signal Corps and Chemical Corps in 1947 to conduct research and development in the field of radiac instrumentation. Because of the past experience in allied instrumentation the Signal Corps conducted work in electronic and photographic fields while the Chemical Corps instituted work in the field of nuclear chemical reactors as applied to dosimetry. Work was conducted within the respective laboratories and in outside commercial laboratories through contract.

A relatively broad program of dosimetry development was undertaken which included improvements of existing available commercial items such as quartz fiber dosimeters, modification and adaptation of current techniques to new problems such as the Polaroid dry-development technique and application of new techniques of dosimetry, items of which are in current development. This development program was undertaken with close coordination with the Navy Department to insure a minimum of duplication of effort.

The results of two years of development were reflected in a test program at Operation GREENHOUSE during which numerous types of dosimeters were tested and evaluated. This evaluation served to place the dosimeters into three categories, (a) those needing minor development to meet military requirements, (b) those needing intermediate development and (c) those needing careful analysis before putting major development efforts thereupon.

The army type dosimeters tested and evaluated under this project are in category (a) and (b) above. The tests constitute a continuation of the previous GREENHOUSE tests in order to provide guidance for the current and future development programs. Two items, namely, the IM-33( )/PD and the DT-65( )/PD are in limited production.

1.3 INSTRUMENTATION

Dosimeters evaluated are listed below. Some are Army developed, some Navy developed equipments.

1.3.1 Army Dosimeters

(a) Radiacmeter IM-33 ( )/PD 3 range quartz fiber, (0-.5), (0-5), (0-50) R

(b) Radiacmeter IM-20( )/PD (K-161) quartz fiber, (0-50)R

(c) Radiacmeter IM-19 ( )/PD (k-151), quartz fiber (0-5)R

(d) Dosimeter, Photographic DT-65/PD, Step Type, (10-403)R

(e) Holder, film, photographic PH-656/PD

(f) Dosimeter, Patterson-Moos, Color step type (0-400)R

1.3.2 Navy Dosimeters

(a) Dosimeter - Glass - DT-60/PD(0-600)R

(b) Dosimeter - Crystal - IM-56/PD, Color Step Type, (0-400)R

1.3.3 Auxiliary Equipment

(a) Bureau of Standards film holders, with DuPont 554 and 556 film.

(b) Three-Curie Co^{60} source.

[redacted]

CHAPTER 2

OPERATIONS

2.1 EXPOSURE

The test dosimeters were exposed to the prompt radiations from each of three air bursts, viz. Baker, Charlie and Dog Shots.

2.1.1 Aluminum Shelter Sites

On each shot the dosimeters were wired to large flat aluminum plates covered with semi-cylindrical aluminum shelters. See Figures 2.1 and 2.2. Each of these assemblies was oriented toward the expected point of detonation, staked to the ground, and braced with guy wire and sand bags. For Baker shot twelve sections were placed at appropriate distances from the intended detonation point to give expected doses of 5 to 2000 roentgens. Each station contained approximately five dosimeters of each type having a range which included the dose expected at that station. On subsequent shots a reduced number of such stations was employed corresponding to an expected dose range of from 5 to 600 roentgens.

2.2 READING AND RECORDING

A few hours after each detonation the dosimeters were removed from the shelters. The quartz-fiber types were read immediately at the Shelter Sites; with the exception of the Patterson-Moos type all other instruments were read upon return to the project station. The Patterson-Moos units were returned to the Army Chemical Center and read there.

2.2.1 Step Devices

Reading of the step types IM-56( )/PD, DT-65/PD, and Patterson-Moos) required special attention. Readings consisted of matching colors or shades of black and white, and it was found that individual readers differed somewhat in their selection. Consequently, a reading panel of several (average of six) persons was set up and all readings of each person for each device recorded. Interpolated readings halfway between steps were permitted. Each reader made his selections in writing

[redacted]

[redacted]
ATOMIC ENERGY ACT 1946

Fig. 2.1 Typical Shelter Site (open)

UNCLASSIFIED

[redacted]

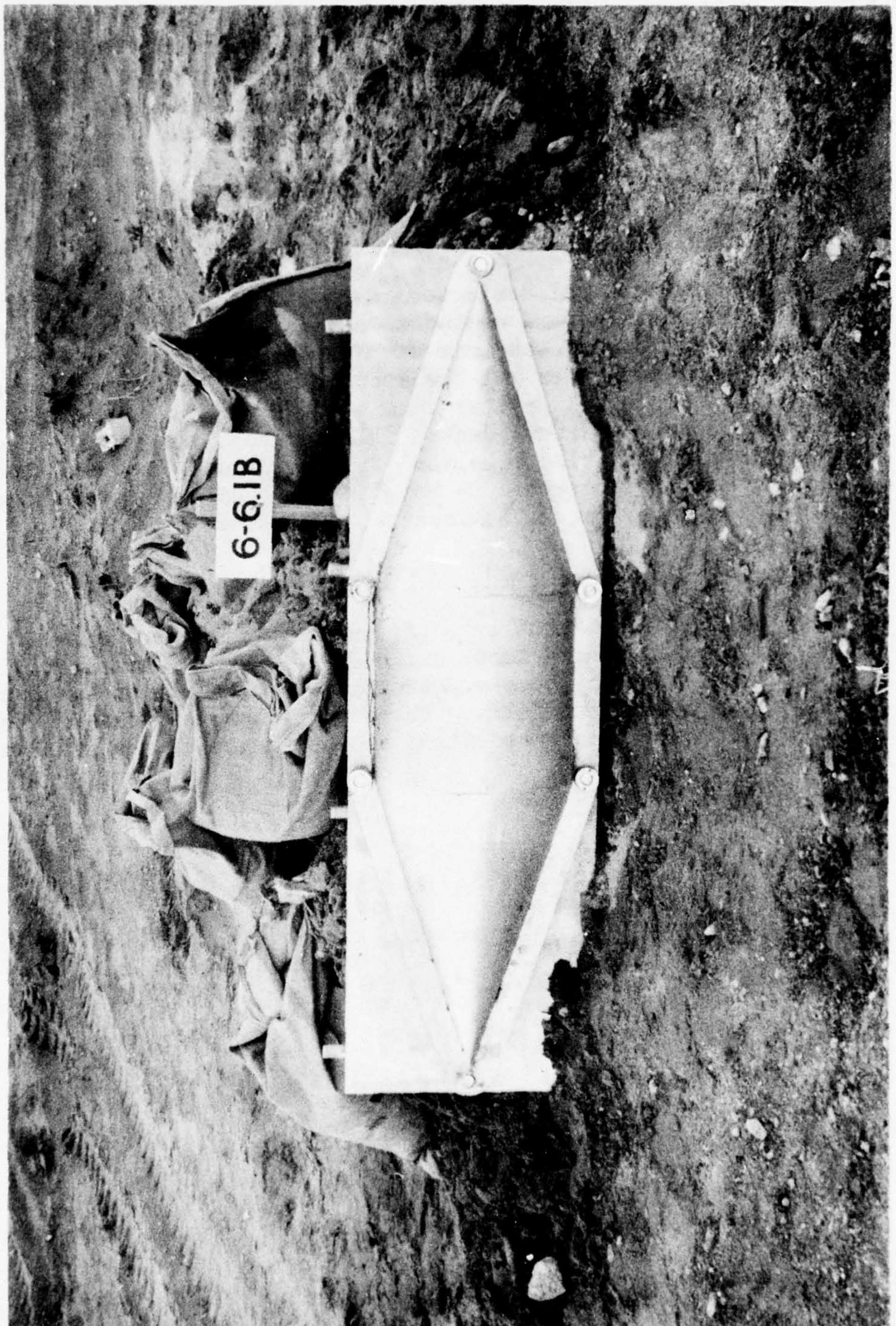

Fig. 2.2 Typical Shelter Site (closed)

[redacted]

UNCLASSIFIED

[redacted]
ATOMIC ENERGY ACT 19[redacted]

[redacted]

and was not previously informed as to the locations of the dosimeters or as to the steps selected by other readers. In analyzing the data, it was necessary to determine a concensus reading for each unit, i.e., the reading of the majority of readers or the average of their readings. This consensus reading was accepted as the true reading of the device.

2.3 CALIBRATION AND CONTROL

2.3.1 CONTROL DOSIMETER

Several control dosimeters were exposed at each station. The readings of these units were accepted as standards, i.e., as the best available approximations of the true dose experienced at each station. These served as the basis for all the accuracy analyses appearing later in this report. These control devices consisted of either DuPont 554 (below 200 r) or 556 (200 r and above) dental film inclosed in National Bureau of Standards type (lead, tin, bakelite) film holders. For a complete discussio of this holder see "Photographic X- and Gammaray Dosimetry" by Margarete Ehrlich and Stephen H. Fitch, Nucleonics, September 1951.

2.3.2 FIELD CALIBRATION AND PROCESSING

Prior to each shot sets of the above film were exposed in N.B.S. holders to known doses from a three curie Co^{60} source. Immediately after each dosimeter recovery the bomb-exposed films were hand-processed simultaneous with a set of the calibrated films. Dose-density curves were plotted in the normal manner from the calibrated films and the doses of the unknown films determined therefrom.

[redacted]

ATOMIC ENERGY ACT 1946

[redacted]

CHAPTER 3

RESULTS AND DISCUSSION

3.1 GENERAL

3.1.1 Scope of Results

All dosimeters were recovered intact. All data was recorded, analyzed, and condensed and is presented herein in appropriate tables and graphs with interpretive discussion. The final object of each data representation is to give an indication of the accuracy (compared to a standard) or consistency of the dosimeter types exposed during this test. No attempt is made to analyze or evaluate any other dosimeter characteristics.

3.1.2 Statistical Limitations

For statistical treatment, the number of samples of each type dosimeter is small. Where all samples read consistently close as in the case of the K-161's and the DT-60's this fact was not serious. However, where several readers disagreed, as in the case of the IM-56, and to a less marked extent, in the case of the DT-65, it was more difficult to interpret the results and to make positive statements about accuracy.

3.1.3 Step Dosimeter Limitations

Analysis of the accuracy of the step-type dosimeters (DT-65/PD, IM-56/PD, Patterson-Moos) was more complex since three principal sources of error came into play. They were as follows:

(a) Inherent step error-inability of device to indicate roentgen values between steps. Between widely spaced steps this limitation may be quite significant.

(b) Response-error-failure of device to indicate correct step i.e., step closest to value of the control dose.

(c) Reader error-disagreement among readers as to which step the device actually indicates.

The step error and the reader error combined in the IM-56 to produce large errors in some readings. In the IM-56, for example the difference in doesage between steps is as high as 200 roentgens. Since in certain cases readers differed by from one-half to one step in reading the dosimeter, errors of as much as 100 and 200 roentgens were introduced. Similarly in the DT-65 readers differed, but since the increments between steps were smaller the resulting error was less. Like the IM-56, the Patterson-Moos Dosimeter is a four-step device covering the 600 roentgen range and is subject to the same type of error.

3.2 OVERALL CONSISTENCY

Table 3.1 shows the average reading of each type dosimeter at each station. In general these readings are in reasonably good agreement. This is an indication of consistency among the different dosimeter types tested. It should be emphasized that each reading given in Table 3.1 is an average of several individual readings which sometimes differ considerably; thus this table cannot be properly used to evaluate the accuracy of any particular type dosimeter, but is only presented to give an indication of the general agreement of all types. In using this table it should be noted that certain dosimeters read in steps. This factor tends to limit agreement between these dosimeters and continuous reading devices (See 3.1.3) Figure 3.1 is a dose-distance chart utilizing the data in Table 3.1 and is a graphical representation of overall consistency.

3.3 CONTROL DOSIMETERS

3.3.1 Consistency

The consistency of the control dosimeter was well demonstrated by the following:

(a) They were consistent at the same location. With very few exceptions the several control dosimeters at each station produced readings within a few per cent of each other. Thus the three control films at station C-7 read 428 r. 428 r. and 452 r. This is a typical case.

[redacted]

TABLE 3.1

Comparison of Average Readings for Each Type Dosimeter at Each Station

Shot	*Distance (ft)	NBS Standard (r)	DT-60/PD (r)	DT-65/PD (r)	IM-56/PD (r)	IM-33/PD (r)	IM-20/PD (r)	IM-19/PD (r)
B	2740	600	650					
	3120	400	365					
	3520	205	216	166	200			
	3620	190		166				
	3900	120	112	77	100			
	4200	77	76	61	100			
	4660	36	39	48-61	50			
	4860	29.5		23-33	BR(a)			
	5160	22.2	18	23	BR	19	21	
	5690	12.2	3.25	10	BR		11.7	
	6330	5.5		BR	BR		5.2	
	6890	2.8		BR	BR		2.8	3.6
C	3920	428	512	339	400			
	4220	282		259	400			
	4700	154	163	122	200			
	5190	76	86	69-77	100-200			
	5710	41	45	44	50-100			
	6370	16.9	18	16.5	BR	18.4	20.7	
	6890	10.1	15	BR			12.0	
D	4210	600	552	AR(b)	AR			
	4700	255	268	234	400			
	4880	200	230	200	200			
	5170	146	160	166	200			
	5610	80	81	77	100			
	6300	36.0	35	40	BR	35	34	
	6800	18.5	17	16.5-23			21.5	

* Distance from dosimeter array to blast
(a) BR denotes below range of device
(b) AR denotes above range of device

[redacted]

[redacted] ATOMIC ENERGY ACT 194

(b) Consistency is also evidenced by the fact that the readings plotted in Figure 3.1 result in smooth curves.

(c) Readings were consistent between the several shots. Note that the curves of Figure 3.1 are approximately parallel and of the same shape.

(d) Readings of the control dosimeters were fairly consistent with the test dosimeter readings. This is apparent from Table 3.1

3.4 RADIACMETER IM-20( )/PD K161

In Table 3.2 (1) are summarized the results for this quartz fiber, 0-50 r, instrument.

TABLE 3.2

Summary of IM-20( )/PD Data

NBS Standard (r)	IM-20( )/PD Average of 8, (r)	Deviation of Average from NBS(%)	Deviation of Individual Readings from Average (%)	
			Maximum	Mean of eight units
2.8	2.8	0.0	29.0	10.7
5.6	5.1	8.9	29.0	10.7
10.0	12.0	20.0	20.0	8.0
12.2	11.7	4.2	19.0	7.4
17.0	20.7	2.2	7.6	3.5
22.2	21.1	5.0	13.1	7.2
20.0	21.5	7.5	7.5	4.5
36.0	34.1	5.3	5.8	3.6
75% of the units indicated within 20% of the standard doses				

The data indicate that 75% of the units tested were accurate to within plus or minus 20%, the accuracy required for military usage.

[redacted]

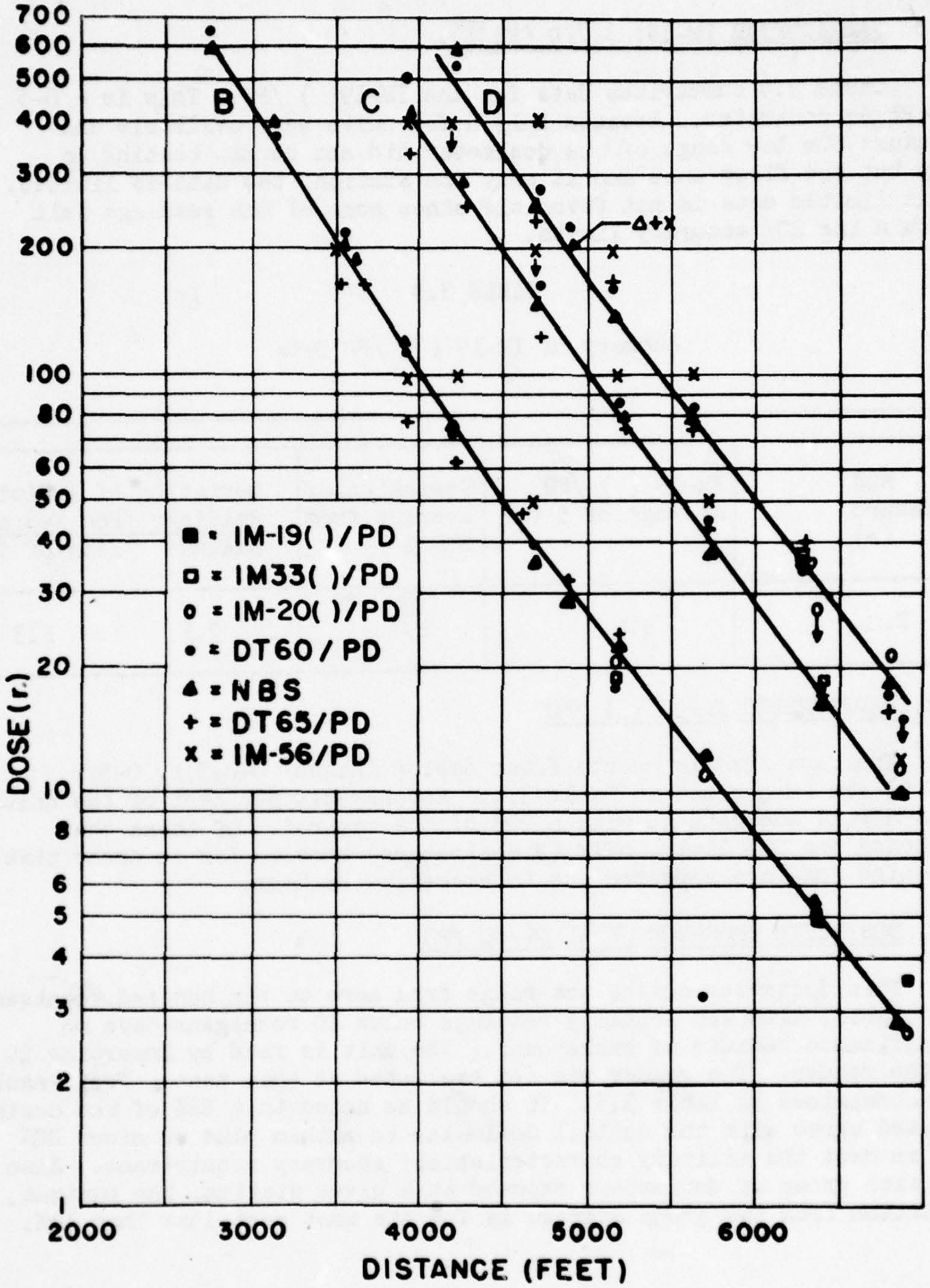

Fig. 3.1 Dose - Distance Chart of Average Readings

[redacted]

[redacted] ATOMIC ENERGY ACT·19[redacted]

3.5 **RADIACMETER** IM-19( ) /PD (K151).

Table 3.3 summarizes data for the IM-19( ) /PD. This is a 0-5 roentgen dosimeter. Because only a few units were available and because the low range of the dosimeter did not permit testing on any but the first shot and at only one station, the data is limited. This limited data is not favorable since none of the readings fell within the 20% accuracy limits.

TABLE 3.3

Summary of IM-19 ( ) /PD Data

NBS Standard (r)	IM-19 ( ) /PD Average of 5 (r)	Deviation of Average from NBS %	Deviation of Individual Readings from Average (%)	
			Maximum	Mean of 5 units
2.8	3.6	29%	7.1	4.3

3.6 **RADIACMETER** IM-33 ( ) /PD

The data for this quartz fiber device (Range: 0-0.5 r, 0-5 r, 0-5 r) are summarized in Table 3.4. Seventy-six per cent of the units tested were accurate to within 20% of the control. Of those that exceeded the 20% limit, half (3 dosimeters) were so far in error that the high readings appeared due to excessive leakage.

3.7 DOSIMETER PHOSPHOR GLASS DT-60 /PD

This dosimeter covers the range from zero to six hundred roentgens and higher, although actually readings below 10 roentgens have no significance because of background. The unit is read by inserting it in the reader. The reader was not evaluated at this test. Test results are summarized in Table 3.5. It should be noted that 82% of the dosimeters tested agree with the control dosimeter to within plus or minus 20% and so meet the military characteristics' accuracy requirement. Also for each group of dosimeters exposed at a given station, the maximum deviation from the group average is for the most part less than 12%.

TABLE 3.4

Summary of IM-33 ( ) /PD Data

NBS Standard (r)	IM-33 ( ) /PD Average of 5 (r)	Deviation of Average from NBS %	Deviation of Individual Readings from Average (%)	
			Maximum	Mean of 5 Units
5.6	5.1	8.9	0.9	0.4
12.2	23	88	21	12.4
16.6	18.4	14.5	2.6	1.7
22.2	19	14.4	0	0
36	35	2.8	3	2.4

76% of the units indicated within 20% of the standard doses

3.8 DOSIMETER PHOTOGRAPHIC DT-65 /PD

This is a step dosimeter. The reader must choose one of twelve steps which is most like the radiation sensitive strip. Interpolated readings halfway between steps may also be selected. Up to eight units were exposed at each station. The exposed units were read by four to ten observers. In the ideal case all readers would report identical steps and all units at each station would have identical indication. The accepted reading for each badge is the consensus reading, i.e., the step picked by a majority of the readers, or , if there was no majority, the average readings. Readers frequently varied by one-half step and occasionally by one step or more. Table 3.7 summarizes the data. An analysis of both the consensus readings (See Sec. 2.2.1) and the individual readings is presented. The former indicate primarily device accuracy and the latter overall accuracy (includes reader error). The consensus readings are also represented graphically in Figure 3.2. The nearest steps to the control readings are plotted horizontally and the consensus readings vertically. Figures in circles represent numbers of devices. It can be seen that in both analyses over 80% of the readings are not in error by more than one-half step. Inspection of Table 3.6 will show that a half step error does not greatly exceed 20% except between steps G and H. Thus the DT-65 /PD has sufficient accuracy for military use except possibly in its "GH region".

[redacted]
ATOMIC ENERGY ACT 1946

TABLE 3.5

Summary of DT-60 Data

NBS Standard (r)	DT-60 Average of 4 to 10 dosimeter readings (r)	Per Cent deviation of average from Standard	Maximum deviation of individual readings from average (%)	Mean deviation from Average (%)
10	15	50.		
12.2	3.2	74.	6.6	7.4
16.9	18	6.6	15.4	10.
20	17	15.	10.	7.5
36	39	8.3	11.	6.1
36	35	2.8	17.	7.8
41	45	9.8	16.	6.6
74	86	16.3	10.	4.1
77	77	0	12.	6.5
118	112	5.1	4.5	2.0
146	160	9.6	8.1	6.3
200	216	8.	2.8	1.5
200	230	15.	2.2	1.1
400	365	8.8	6.9	2.7
600	552	8.	1.9	1.0
648	638	1.5	18.7	6.1

82% of the units indicated within ± 20% of the standard doses

TABLE 3.6

Steps of DT-65/PD

Step (a)	Dose	Step	Dose
A	10r	G	77r
B	23r	H	166r
C	33r	I	234r
D	40r	J	284r
E	48r	K	339r
F	61r	L	403r

(a) For roentgen values of half-steps, take the arithmetic mean of the roentgen values of the two adjacent full steps.

3.9 <u>CASUALTY DOSIMETER</u> - <u>CRYSTAL TYPE IM-56( )/PD</u>

The IM-56( )/PD data is summarized in Table 3.8. This table shows the step selected by the majority of those reading the dosimeters. It compares the step selected in this way with the step nearest to the dose read on the control film at each station. Using this consensus method 72% of the dosimeters agreed with the control film, 7% were half a step off, and 19% were a full step off.

This appears to be a favorable result. Actually the significance of this result is not clear. In the first place even if the correct step is chosen, there may be a large error due to the range of the step. Secondly, there may be ambiguity about which is the correct step. If the true dose is 29 roentgens, is the correct step 50 roentgens, or is it to be reported as "BR" for below range? Thirdly, ought the reader try to interpolate? How significant is it to report 150 roentgens, if the color lies in the region between 100 and 200 roentgens? Even though the consensus is correct, what are the chances that an individual observation will have an accuracy that will make the dosage reported significant? It does appear that the majority of readers report values within half a step of the step whose range includes the true value. However, this half step may represent more than a hundred roentgens in a region where a variation of 50 or 25 roentgens is significant. Variations among readers are illustrated in Table 3.9 which gives typical sets of reported readings. This table shows the difficulty of determining

TABLE 3.7
DT-65/PD Results

Control Reading (r)	Nearest Step	Consensus (a) Reading	Number of Readings (a) Total	Correct	½ Step Off	Full Step Off	Other
2.8	BR(b)	7-BR	49	49	0	0	0
5.6	BR	7-BR	49	42	7	0	0
10.1	A	5-BR,2-A	28	10	18	0	0
12.2	A	5-A,2-AB	44	31	10	3	0
16.9	AB	2-A,4-AB,1-B	28	16	12	0	0
18.5	AB	3-AB,4-B	28	9	17	1	1
22.2	B	6-B,1-BC	49	28	20	1	0
29.5	BC	3-B,3-C	24	7	17	0	0
35	CD	2-D,2-E	28	0	7	4	17
36	CD	1-D,3-E,3-F	49	0	4	5	40
36	CD	6-D,1-E	42	1	25	8	8
41	D	1-D,3-DE,3-E	28	2	14	8	4
76	G	4-FG,3-G	28	16	9	3	0
77	G	6-G	56	56	0	0	0
80	G	7-G	42	40	1	1	0
120	GH	6-G,1-GH	49	7	42	0	0
146	H	5-H	33	30	3	0	0
.54	H	2-G,5-GH	35	1	24	10	0

a) Each dosimeter was examined by a panel of readers and all readings recorded (See Sec. 2.2). A concensus reading was determined for each individual dosimeter.

b) BR indicates a dose below the range of the dosimeter.

TABLE 3.7 (Cont.)

Control Reading (r)	Nearest Step	Consensus(a) Reading	Number of Readings(a)				
			Total	Correct	½Step Off	FullStep Off	Other
190	HI	8-H	48	0	44	4	0
200	HI	1-H,4-HI,2-I	40	10	29	1	0
205	HI	5-H,1-HI	53	11	38	4	0
255	IJ	7-I	39	7	22	10	0
282	J	1-I,5-IJ,1-J	35	4	19	12	0
428	L	7-K	35	0	6	27	2
600	AR(c)	1-K,2-L,3-AR	34	11	19	2	2
Accuracy of Individual Readings		Total	973	388	407	104	74
		% of Total	100	40	42	11	7
Accuracy of Consensus Readings			%(d)	Correct	½Step Off	FullStep Off	Other
				44	44	7	6

(c) AR indicates a dose above range.
(d) Since results are rounded off, sum does not total %100

consensus readings. For these reasons it is difficult to conclude more than that the IM-56( )/Pd is only a rough indicator of dosage. The limited data of this test does not permit a statistical statement about the accuracy of any given dosimeter reading. It is clear that observed readings on the same dosimeter may vary by more than 100 roentgens. It would be desireable to obtain information on the accuracy of any given IM-56( )/PD by carrying out a test using an adequate number of samples. It is also clear that the statistics can be improved by making certain design modifications in the IM-56( )/PD and by giving the reader a slight amount of training.

UNCLASSIFIED

[redacted]

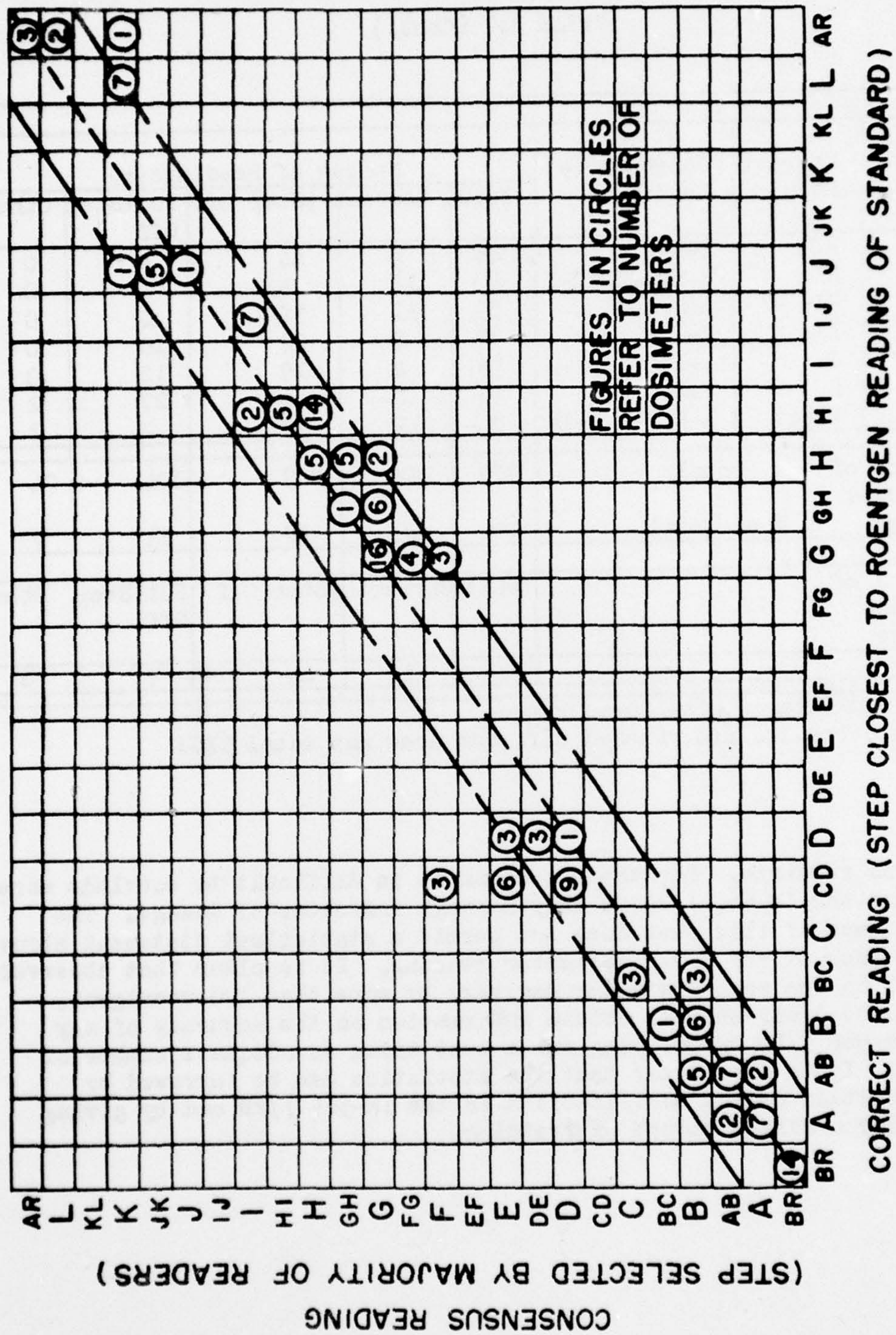

Fig. 3.2 Accuracy of DT-65( )/PD Based on Consensus Readings

[redacted]
ATOMIC ENERGY ACT 1946

[redacted]

UNCLASSIFIED

[redacted]

TABLE 3.8

Summary of IM-56( )/PD Data

NBS Film Reading (r)	IM-56( )/PD Step related to NBS Film Reading (r)	IM-56( )/PD selected by Majority of readers (r)
12.2	BR (Below range of lowest step)	(4) BR
16.6	BR	(3) BR, (2) 50
22.2	BR	(4) BR
29.5	BR or 50	(3) BR, (2) 50
36	BR or 50	(5) 50
33	BR or 50	(3) 50, (1) BR
41	50	(3) 50, (2) 100
76	50 or 100	(3) 100, (2) 200
77	50 or 100	(5) 100
80	100	(5) 100
120	100	(2) 100, (3) 200
146	100 or 200	(4) 200
185	200	(5) 200
200	200	(4) 200, (1) 300
200	200	(1) 200, (3) 300
254	200 or 300	(2) 300, (3) 400
282	200	(3) 100, (2) 50
428	400 or AR(above range	(3) 300, (1) 400, (1) AR
600	AR (Above range)	(4) AR

[redacted]

[redacted]
ATOMIC ENERGY ACT 1946

TABLE 3.9

Samples of IM-56 ( )/PD
Raw Data

SN (a) of IM-56	NBS Dose (r)	Nearest Step (r)	Readings of Different Readers (r) #1	#2	#3	#4	#5	#6	#7	Consensus Rdgs (r)
181	35	BR	50-100	<50	0	50	50-	50-	100-	BR(b)
182		or	50	<50	50	50	50	50-	100-	50
183		50	50-100	50	50	50	50-	50-	50+	50
184			50-	<50	0	50	50	50-	50+	50
165	41		50	25	50	75				50
166		50	50	50	50	75				50
167			50	25	100	100				50
168			100	25	75	150				100
170			100	25	75	100				100
157	77		100-200	50	150	100	100	50-	100	100
211		50 or	100	50	200	200	100	50	100	100
212		100	100	75	100	100	100	100	100	100
213			100	50	150	200	100	100-	200	150
214			100	50	100	100	100	50-	100	100
255	200		300	300	300	300	200	200		300
256		200	300	300	300	300	200	200		300
257			300	300	200	300	200	200		300
263			300	300	300	400+	200	200		300

(a) SN denotes serial numbers.
(b) BR indicates a reading below the range of the dosimeter.

[redacted]

3.10 PATTERSON MOOS DOSIMETER

The Patterson Moos dosimeters were read at the Army Chemical Center by a panel of seven persons. A copy of the data was transmitted to Project 6.1b and is presented in modified form in Table 3.10. Only the concensus of all readings for each dosimeter is reported. Thus the information concerning reader error (see Sec. 3.1.3) is shown. The data indicates that this type dosimeter is not sufficiently accurate for military use.

TABLE 3.10

Summary of Patterson Moos Data

Standard Reading (r)	Nearest Step (r)	No. Dosimeters Giving Indicated Readings				
		0 r	50 r	100 r	200 r	500 r
12.2		5				
17	0	5				
18.5		5				
22		4				
29.5		4				
36	50	3				
36		8				
41		5				
76		4	2			
77		4	1			
80	100	2	1			
120		2	1			
146		1	5	1		
154		5	3			
190		1	2	3		
200			3	3	2	
205	200	1	3			
252				2	7	
255				2	4	
545	400				2	3

[redacted]

CHAPTER 4

CONCLUSIONS AND RECOMMENDATIONS

4.1 QUARTZ FIBER DOSIMETERS. (IM-20( )/PD; IM-19( )/PD: IM-33 ( )/PD

The IM-20( )/PD, 0-50 r dosimeter and the IM-33( )/PD, 0-5, 0-5, and 0-50 r dosimeter were found to be sufficiently accurate for the measurement of prompt radiation. The IM-19( )/PD dosimeters tested exceeded the accuracy limits of the military characteristics, 20%, but not enough data was obtained to warrant a conclusion. Based on these conclusions continued procurement of the IM-20( )/PD and IM-33 ( )/PD is recommended provided that these equipments are satisfactory with respect to all other military requirements.

4.2 PHOSPHOR GLASS DOSIMETER, HIGH RANGE, DT-60( )/PD.

The DT-60( )/PD was found to be sufficiently accurate for the measurement of prompt radiation. Procurement of DT-60( )/PD to satisfy the need for a high-range, non-self indicating device is recommended provided that the equipment satisfies all other military requirements.

4.3 DOSIMETER PHOTOGRAPHIC. DT-65( )/PD

The DT-65( )/PD has sufficient accuracy for military use except in its GH region, where the change in dosage from G to H is 77 to 166 roentgens. For this reason it is recommended that the dose increment between steps G and H be reduced in order to increase accuracy in this range. It is also recommended that the steps be more uniformly spaced. Meanwhile it is recommended that the present equipment be procured to satisfy the need for a high-range, self-indicating dosimeter, provided that other military requirements are satisfactorily fulfilled.

4.4 CASUALTY DOSIMETER - CRYSTAL TYPE IM-56( )/PD

Variations in readings reported by different observers make the IM-56( )/PD unsuitable in its present form. This is partly due to the large dosage range of the individual steps.

4.5 PATTERSON MOOS DOSIMETER

Readings on the Patterson Moos dosimeters indicate that this device in the form tested did not have sufficient accuracy for military use.

4.6 A FOUR STEP DOSIMETER

A four-step dosimeter of the IM-56( )/PD type has serious accuracy limitations because of the magnitude of the dose increments between successive steps. This makes it impossible to satisfy the military requirements for ±20% accuracy specified in the military characteristics. It is therefore recommended that the need for such a dosimeter be re-examined and that appropriate accuracy specifications be established.

DISTRIBUTION

ARMY ACTIVITIES

	Copy No.
Asst. Chief of Staff, G-1, Department of the Army, Washington 25, D. C.	1
Asst. Chief of Staff, G-2, Department of the Army, Washington 25, D. C.	2
Asst. Chief of Staff, G-3, Department of the Army, Washington 25, D. C.	3- 6
Asst. Chief of Staff, G-4, Department of the Army, Washington 25, D. C.	7- 11
Chief of Ordnance, Department of the Army, Washington 25, D. C.	12- 14
Chief Chemical Officer, Temp. Bldg. T-7, Room G-522, Gravelly Point, Va.	15- 18
Chief of Engineers, Temp. Bldg. T-7, Room G-425, Gravelly Point, Va.	19- 21
The Quartermaster General, Second and T Sts. SW, Room 1139A, Washington 25, D. C.	22- 26
Chief of Transportation, Temp. Bldg, T-7, Room G-816, Gravelly Point, Va.	27- 28
Chief Signal Officer, Department of the Army, Washington 25, D. C.	29- 31
The Surgeon General, Main Navy Bldg., Room 1651, Washington 25, D. C.	32- 34
Provost Marshal General, Main Navy Bldg., Room 1065, Washington 25, D. C.	35- 37
Chief, Army Field Forces, Fort Monroe, Va.	38- 41
President, Army Field Forces Board No. 1, Fort Bragg, N. C.	42
President, Army Field Forces Board No. 2, Fort Knox, Ky.	43
President, Army Field Forces Board No. 3, Fort Benning, Ga.	44
President, Army Field Forces Board No. 4, Fort Bliss, Tex.	45
Commandant, The Infantry School, Fort Benning, Ga.	46- 47
Commandant, The Armored School, Fort Knox, Ky.	48- 49
President, The Artillery School Board, Fort Sill, Okla.	50- 51
Commandant, The AA&GM Branch, The Artillery School, Fort Bliss, Tex.	52- 53
Commandant, Army War College, Carlisle Barracks, Pa.	54- 55
Commandant, Command and General Staff College, Fort Leavenworth, Kans.	56- 57
Commandant, Army General School, Fort Riley, Kans.	58

[redacted]

DISTRIBUTION (Continued)

	Copy No.
Commanding General, First Army, Governor's Island, New York 4, N. Y.	59- 60
Commanding General, Second Army, Fort George G. Meade, Md.	61- 62
Commanding General, Third Army, Fort McPherson, Ga.	63- 64
Commanding General, Fourth Army, Fort Sam Houston, Tex.	65- 66
Commanding General, Fifth Army, 1660 E. Hyde Park Blvd., Chicago 15, Ill.	67- 68
Commanding General, Sixth Army, Presidio of San Francisco, Calif.	69- 70
Commander-in-Chief, European Command, APO 403, c/o Postmaster, New York, N. Y.	71- 72
Commander-in-Chief, Far East, APO 500, c/o Postmaster, San Francisco, Calif.	73- 74
Commanding General, U. S. Army, Pacific, APO 958, c/o Postmaster, San Francisco, Calif.	75- 76
Commanding General, U. S. Army, Caribbean, APO 834, c/o Postmaster, New Orleans, La.	77- 78
Commanding General, U. S. Army, Alaska, APO 942, c/o Postmaster, Seattle, Wash.	79- 80
Director, Operations Research Office, 6410 Connecticut Ave., Chevy Chase, Md.	81- 83
Commanding Officer, Ballistic Research Laboratories, Aberdeen Proving Ground, Aberdeen, Md.	84- 85
Commanding Officer, Engineer Research and Development Laboratory, Fort Belvoir, Va.	86- 87
Commanding Officer, Signal Corps Engineering Laboratories, Fort Monmouth, N. J.	88- 89
Commanding Officer, Evans Signal Laboratory, Belmar, N. J.	90- 91
Commanding General, Army Chemical Center, Md. ATTN: Chemical and Radiological Laboratory	92- 93

NAVY ACTIVITIES

Chief of Naval Operations, Department of the Navy, Washington 25, D. C. ATTN: Op-36	94- 95
Chief, Bureau of Ships, Department of the Navy, Washington 25, D. C.	96- 99
Chief, Bureau of Ordnance, Department of the Navy, Washington 25, D. C.	100
Chief, Bureau of Medicine and Surgery, Department of the Navy, Washington 25, D. C.	101-102
Chief, Bureau of Aeronautics, Department of the Navy, Washington 25, D. C.	103-104
Chief, Bureau of Supplies and Accounts, Department of the Navy, Washington 25, D. C.	105-106
Chief, Bureau of Yards and Docks, Department of the Navy, Washington 25, D. C.	107-109

[redacted]
ATOMIC ENERGY ACT 1946

[redacted]

DISTRIBUTION (Continued)

	Copy No.
Chief of Naval Personnel, Department of the Navy, Washington 25, D. C.	110
Commandant of the Marine Corps, Washington 25, D. C.	111-113
Commander-in-Chief, U. S. Pacific Fleet, Fleet Post Office, San Francisco, Calif.	114
Commander-in-Chief, U. S. Atlantic Fleet, Fleet Post Office, New York, N. Y.	115
President, U. S. Naval War College, Newport, R. I.	116
Commandant, Marine Corps Schools, Quantico, Va.	117-118
Chief of Naval Research, Department of the Navy, Washington 25, D. C.	119-120
Commander, U. S. Naval Ordnance Laboratory, Silver Spring 19, Md.	121
Commander, U. S. Naval Ordnance Laboratory, Silver Spring 19, Md. ATTN: Aliex	122
Director, U. S. Naval Research Laboratory, Washington 25, D. C.	123
Commanding Officer and Director, U. S. Naval Electronics Laboratory, San Diego 52, Calif.	124
Commanding Officer, U. S. Naval Radiological Defense Laboratory, San Francisco 24, Calif.	125-128
Commanding Officer and Director, David Taylor Model Basin, Washington 7, D. C.	129
Commander, Naval Material Laboratory, New York Naval Shipyard, Naval Base, New York 1, N. Y.	130
Officer-in-Charge, U. S. Naval Civil Engineering Research and Evaluation Laboratory, U. S. Naval Construction Battalion Center, Port Hueneme, Calif.	131-132
Commanding Officer, U. S. Naval Medical Research Institute, National Naval Medical Center, Bethesda 14, Md.	133
Commander, U. S. Naval Ordnance Test Station, Inyokern, China Lake, Calif.	134

AIR FORCE ACTIVITIES

Assistant for Atomic Energy, Headquarters, United States Air Force, Washington 25, D. C.	135-136
Director of Operations, Headquarters, United States Air Force, Washington 25, D. C. ATTN: Operations Analysis Division	137-138
Director of Plans, Headquarters, United States Air Force, Washington 25, D. C. ATTN: AFOPD-P1	139
Director of Requirements, Headquarters, United States Air Force, Washington 25, D. C.	140
Director of Research and Development, Headquarters, United States Air Force, Washington 25, D. C.	141-142
Director of Intelligence, Headquarters, United States Air Force, Washington 25, D. C. ATTN: Phys. Vul. Branch, Air Targets Division	143-144

DISTRIBUTION (Continued)

	Copy No.
Director of Installations, Headquarters, United States Air Force, Washington 25, D. C.	145
Asst. for Development Planning, Headquarters, United States Air Force, Washington 25, D. C.	146
Asst. for Materiel Program Control, Headquarters, United States Air Force, Washington 25, D. C.	147
The Surgeon General, Headquarters, United States Air Force, Washington 25, D. C.	148
Commanding General, Strategic Air Command, Offutt Air Force Base, Nebr.	149-151
Commanding General, Air Research and Development Command, P.O. Box 1395, Baltimore 3, Md.	152-161
Commanding General, Air Materiel Command, Wright-Patterson Air Force Base, Dayton, Ohio	162-163
Commanding General, Air Materiel Command, Wright-Patterson Air Force Base, Dayton, Ohio. ATTN: Air Installations Division	164-165
Commanding General, Tactical Air Command, Langley Air Force Base, Va.	166-168
Commanding General, Air Defense Command, Ent Air Force Base, Colo.	169-171
Commanding General, Air Proving Ground, Eglin Air Force Base, Fla.	172-173
Commanding General, Air Training Command, Scott Air Force Base, Belleville, Ill.	174-176
Commanding General, Air University, Maxwell Air Force Base, Montgomery, Ala.	177-179
Commanding General, Special Weapons Center, Kirtland Air Force Base, N. Mex.	180-182
Commanding General, 1009th Special Weapons Squadron, 1712 G St. NW, Washington 25, D. C.	183
Commanding General, Wright Air Development Center, Wright-Patterson Air Force Base, Dayton, Ohio	184-187
Commanding General, Air Force Cambridge Research Center, 230 Albany St., Cambridge 39, Mass.	188-189
Commanding General, U. S. Air Forces in Europe, APO 633, c/o Postmaster, New York, N. Y.	190-191
Commanding General, Far East Air Forces, APO 925, c/o Postmaster, San Francisco, Calif.	192-193
Commanding General, Air Force Missile Center, Patrick Air Force Base, Cocoa, Fla.	194
Commandant, USAF School of Aviation Medicine, Randolph Air Force Base, Randolph Field, Tex.	195
Asst. to the Special Asst., Chief of Staff, United States Air Force, Washington 25, D. C. ATTN: David T. Griggs	196
The RAND Corporation, 1500 Fourth St., Santa Monica, Calif.	197-198

UNCLASSIFIED

[redacted]

DISTRIBUTION (Continued)

AFSWP ACTIVITIES

	Copy No.
Chief, Armed Forces Special Weapons Project, P.O. Box 2610, Washington 13, D. C.	199-207
Commanding General, Field Command, Armed Forces Special Weapons Project, P.O. Box 5100, Albuquerque, N. Mex.	208-210
Commanding Officer, Test Command, Armed Forces Special Weapons Project, P.O. Box 5600, Albuquerque, N. Mex.	211-213

OTHER ACTIVITIES

Chairman, Research and Development Board, Department of Defense, Washington 25, D. C.	214
Director, Weapons System Evaluations Group, Office of the Secretary of Defense, Washington 25, D. C.	215
Executive Director, Committee on Atomic Energy, Research and Development Board, Department of Defense, Washington 25, D. C. ATTN: David Beckler	216
Executive Director, Committee on Medical Sciences, Research and Development Board, Department of Defense, Washington 25, D. C.	217
U. S. Atomic Energy Commission, Classified Document Room, 1901 Constitution Ave., Washington 25, D. C. ATTN: Mrs. J. M. O'Leary	218-220
Los Alamos Scientific Laboratory, Report Library, P.O. Box 1663, Los Alamos, N. Mex. ATTN: Helen Challenger	221-223
Sandia Corporation, Classified Document Division, Sandia Base, Albuquerque, N. Mex. ATTN: Wynne K. Cox	224-243
Commanding General, Wright Air Development Center, Wright-Patterson Air Force Base, Dayton, Ohio ATTN: WCEEI-4, Maj. H. E. Kee, Jr.	244
Weapon Test Reports Group, TIS	245
Surplus in TISOR for DMA	246-295
Surplus in TISOR for AFSWP	296-345

[redacted]

AEC, Oak Ridge, Tenn., A28049

UNCLASSIFIED

[redacted]

ATOMIC ENERGY ACT 1946